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National Semiconductor

August 2002

**Jameco Part Number 23309**

# LM193/LM293/LM393/LM2903
# Low Power Low Offset Voltage Dual Comparators

## General Description

The LM193 series consists of two independent precision voltage comparators with an offset voltage specification as low as 2.0 mV max for two comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM193 series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM193 series will directly interface with MOS logic where their low power drain is a distinct advantage over standard comparators.

The LM393 and LM2903 parts are available in National's innovative thin micro SMD package with 8 (12 mil) large bumps.

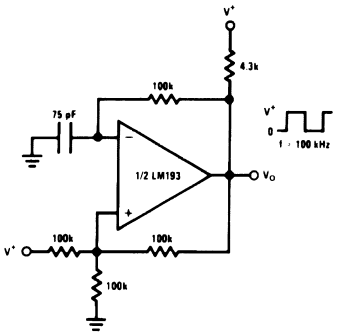
## Advantages

- High precision comparators
- Reduced $V_{OS}$ drift over temperature
- Eliminates need for dual supplies
- Allows sensing near ground
- Compatible with all forms of logic
- Power drain suitable for battery operation

## Features

- Wide supply
  - — Voltage range: 2.0V to 36V
  - — Single or dual supplies: ±1.0V to ±18V
- Very low supply current drain (0.4 mA) — independent of supply voltage
- Low input biasing current: 25 nA
- Low input offset current: ±5 nA
- Maximum offset voltage: ±3 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage,: 250 mV at 4 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems
- Available in the 8-Bump (12 mil) micro SMD package
- See AN-1112 for micro SMD considerations

**Squarewave Oscillator**

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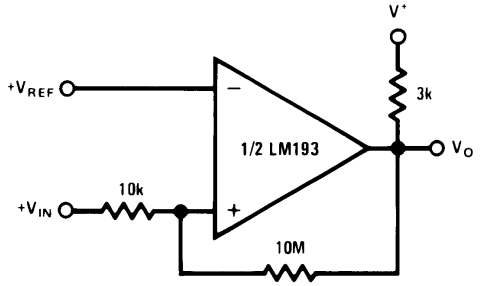
**Non-Inverting Comparator with Hysteresis**

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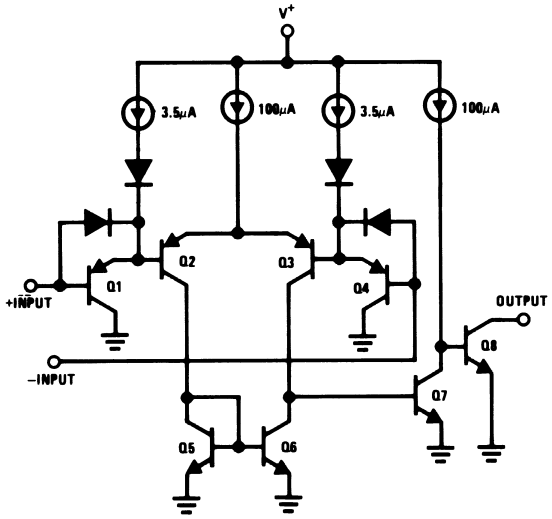
## Schematic and Connection Diagrams

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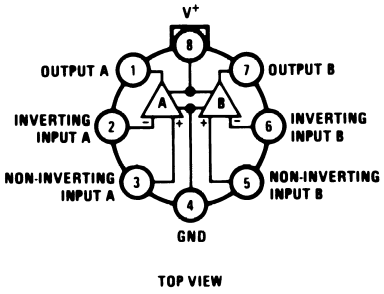
**Metal Can Package**




TOP VIEW

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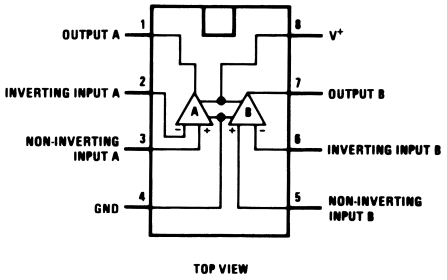
**Dual-In-Line/SOIC Package**




TOP VIEW

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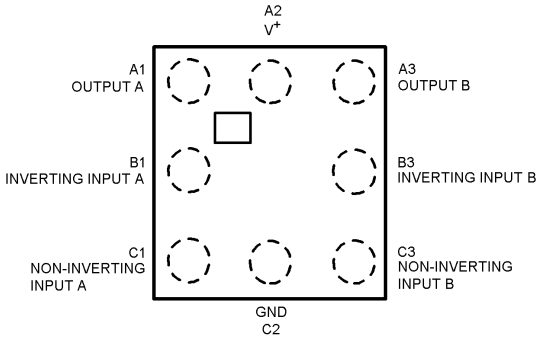
**micro SMD**

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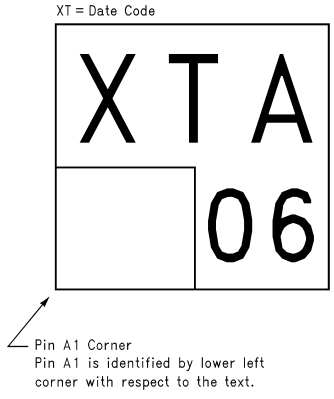
**Top View**

**micro SMD Marking**

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**Top View**

## Absolute Maximum Ratings (Note 10)

**If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.**

| | |
|---|---|
| Supply Voltage, $V^+$ | 36V |
| Differential Input Voltage (Note 8) | 36V |
| Input Voltage | −0.3V to +36V |
| Input Current ($V_{IN}$<−0.3V) (Note 3) | 50 mA |
| Power Dissipation (Note 1) | |
| Molded DIP | 780 mW |
| Metal Can | 660 mW |
| Small Outline Package | 510 mW |
| micro SMD Pacakge | 568mW |
| Output Short-Circuit to Ground | |
| (Note 2) | Continuous |
| Operating Temperature Range | |
| LM393 | 0˚C to +70˚C |
| LM293 | −25˚C to +85˚C |
| LM193/LM193A | −55˚C to +125˚C |
| LM2903 | −40˚C to +85˚C |
| Storage Temperature Range | −65˚C to +150˚C |
| Lead Temperature | |
| (Soldering, 10 seconds) | +260˚C |
| Soldering Information | |
| Dual-In-Line Package | |
| Soldering (10 seconds) | 260˚C |
| Small Outline Package | 215˚C |
| Vapor Phase (60 seconds) | |
| Infrared (15 seconds) | 220˚C |

See AN-450 “Surface Mounting Methods and Their Effect on Product Reliability” for other methods of soldering surface mount devices.

| | |
|---|---|
| ESD rating | |
| (1.5 kΩ in series with 100 pF) | 1300V |

## Electrical Characteristics

($V^+$=5V, $T_A$ = 25˚C, unless otherwise stated)

| Parameter | Conditions | | LM193A | | | Units |
|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | |
| Input Offset Voltage | (Note 9) | | | 1.0 | 2.0 | mV |
| Input Bias Current | $I_{IN}(+)$ or $I_{IN}(-)$ with Output In Linear Range, $V_{CM}$ = 0V (Note 5) | | | 25 | 100 | nA |
| Input Offset Current | $I_{IN}(+)-I_{IN}(-)$ $V_{CM}$ = 0V | | | 3.0 | 25 | nA |
| Input Common Mode Voltage Range | V+ = 30V (Note 6) | | 0 | | $V^+$−1.5 | V |
| Supply Current | $R_L=\infty$ | $V^+$=5V | | 0.4 | 1 | mA |
| | | $V^+$=36V | | 1 | 2.5 | mA |
| Voltage Gain | $R_L$≥15 kΩ, $V^+$=15V $V_O$ = 1V to 11V | | 50 | 200 | | V/mV |
| Large Signal Response Time | $V_{IN}$=TTL Logic Swing, $V_{REF}$=1.4V $V_{RL}$=5V, $R_L$=5.1 kΩ | | | 300 | | ns |
| Response Time | $V_{RL}$=5V, $R_L$=5.1 kΩ (Note 7) | | | 1.3 | | µs |
| Output Sink Current | $V_{IN}(-)$=1V, $V_{IN}(+)$=0, $V_O$≈1.5V | | 6.0 | 16 | | mA |
| Saturation Voltage | $V_{IN}(-)$=1V, $V_{IN}(+)$=0, $I_{SINK}$≤4 mA | | | 250 | 400 | mV |
| Output Leakage Current | $V_{IN}(-)$=0, $V_{IN}(+)$=1V, $V_O$=5V | | | 0.1 | | nA |

## Electrical Characteristics

($V^+$=5V, $T_A$ = 25˚C, unless otherwise stated)

| Parameter | Conditions | LM193 | | | LM293, LM393 | | | LM2903 | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | (Note 9) | | 1.0 | 5.0 | | 1.0 | 5.0 | | 2.0 | 7.0 | mV |
| Input Bias Current | $I_{IN}(+)$ or $I_{IN}(-)$ with Output In Linear Range, $V_{CM}$ = 0V (Note 5) | | 25 | 100 | | 25 | 250 | | 25 | 250 | nA |
| Input Offset Current | $I_{IN}(+)-I_{IN}(-)$ $V_{CM}$ = 0V | | 3.0 | 25 | | 5.0 | 50 | | 5.0 | 50 | nA |
| Input Common Mode Voltage Range | V+ = 30V (Note 6) | 0 | | V+−1.5 | 0 | | V+−1.5 | 0 | | V+−1.5 | V |

## Electrical Characteristics (Continued)

($V^+$=5V, $T_A$ = 25˚C, unless otherwise stated)

| Parameter | Conditions | | LM193 | | | LM293, LM393 | | | LM2903 | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Supply Current | $R_L$=∞ | $V^+$=5V | | 0.4 | 1 | | 0.4 | 1 | | 0.4 | 1.0 | mA |
| | | $V^+$=36V | | 1 | 2.5 | | 1 | 2.5 | | 1 | 2.5 | mA |
| Voltage Gain | $R_L$≥15 kΩ, $V^+$=15V<br>$V_O$ = 1V to 11V | | 50 | 200 | | 50 | 200 | | 25 | 100 | | V/mV |
| Large Signal Response Time | $V_{IN}$=TTL Logic Swing, $V_{REF}$=1.4V<br>$V_{RL}$=5V, $R_L$=5.1 kΩ | | | 300 | | | 300 | | | 300 | | ns |
| Response Time | $V_{RL}$=5V, $R_L$=5.1 kΩ (Note 7) | | | 1.3 | | | 1.3 | | | 1.5 | | µs |
| Output Sink Current | $V_{IN}(-)$=1V, $V_{IN}(+)$=0, $V_O$≤1.5V | | 6.0 | 16 | | 6.0 | 16 | | 6.0 | 16 | | mA |
| Saturation Voltage | $V_{IN}(-)$=1V, $V_{IN}(+)$=0, $I_{SINK}$≤4 mA | | | 250 | 400 | | 250 | 400 | | 250 | 400 | mV |
| Output Leakage Current | $V_{IN}(-)$=0, $V_{IN}(+)$=1V, $V_O$=5V | | | 0.1 | | | 0.1 | | | 0.1 | | nA |

## Electrical Characteristics

(V+ = 5V) (Note 4)

| Parameter | Conditions | LM193A | | | Units |
|---|---|---|---|---|---|
| | | Min | Typ | Max | |
| Input Offset Voltage | (Note 9) | | | 4.0 | mV |
| Input Offset Current | $I_{IN(+)}$–$I_{IN(-)}$, $V_{CM}$=0V | | | 100 | nA |
| Input Bias Current | $I_{IN}(+)$ or $I_{IN}(-)$ with Output in Linear Range, $V_{CM}$=0V (Note 5) | | | 300 | nA |
| Input Common Mode Voltage Range | $V^+$=30V (Note 6) | 0 | | $V^+$–2.0 | V |
| Saturation Voltage | $V_{IN}(-)$=1V, $V_{IN}(+)$=0, $I_{SINK}$≤4 mA | | | 700 | mV |
| Output Leakage Current | $V_{IN}(-)$=0, $V_{IN(+)}$=1V, $V_O$=30V | | | 1.0 | µA |
| Differential Input Voltage | Keep All $V_{IN}$'s≥0V (or $V^-$, if Used), (Note 8) | | | 36 | V |

## Electrical Characteristics

(V+ = 5V) (Note 4)

| Parameter | Conditions | LM193 | | | LM293, LM393 | | | LM2903 | | | Units |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage | (Note 9) | | | 9 | | | 9 | | 9 | 15 | mV |
| Input Offset Current | $I_{IN(+)}$–$I_{IN(-)}$, $V_{CM}$=0V | | | 100 | | | 150 | | 50 | 200 | nA |
| Input Bias Current | $I_{IN}(+)$ or $I_{IN}(-)$ with Output in Linear Range, $V_{CM}$=0V (Note 5) | | | 300 | | | 400 | | 200 | 500 | nA |
| Input Common Mode Voltage Range | $V^+$=30V (Note 6) | 0 | | $V^+$–2.0 | 0 | | $V^+$–2.0 | 0 | | $V^+$–2.0 | V |
| Saturation Voltage | $V_{IN}(-)$=1V, $V_{IN}(+)$=0, $I_{SINK}$≤4 mA | | | 700 | | | 700 | | 400 | 700 | mV |
| Output Leakage Current | $V_{IN}(-)$=0, $V_{IN(+)}$=1V, $V_O$=30V | | | 1.0 | | | 1.0 | | | 1.0 | µA |
| Differential Input Voltage | Keep All $V_{IN}$'s≥0V (or $V^-$, if Used), (Note 8) | | | 36 | | | 36 | | | 36 | V |

**Note 1:** For operating at high temperatures, the LM393 and LM2903 must be derated based on a 125˚C maximum junction temperature and a thermal resistance of 170˚C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM193/LM193A/LM293 must be derated based on a 150˚C maximum junction temperature. The low bias dissipation and the "ON-OFF" characteristic of the outputs keeps the chip dissipation very small ($P_D$≤100 mW), provided the output transistors are allowed to saturate.

**Note 2:** Short circuits from the output to $V^+$ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 20 mA independent of the magnitude of $V^+$.

**Note 3:** This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action

## Electrical Characteristics (Continued)

on the IC chip. This transistor action can cause the output voltages of the comparators to go to the $V^+$ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3V.

**Note 4:** These specifications are limited to $-55^\circ C \le T_A \le +125^\circ C$, for the LM193/LM193A. With the LM293 all temperature specifications are limited to $-25^\circ C \le T_A \le +85^\circ C$ and the LM393 temperature specifications are limited to $0^\circ C \le T_A \le +70^\circ C$. The LM2903 is limited to $-40^\circ C \le T_A \le +85^\circ C$.

**Note 5:** The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the reference or input lines.

**Note 6:** The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3V. The upper end of the common-mode voltage range is $V^+$–1.5V at 25˚C, but either or both inputs can go to 36V without damage, independent of the magnitude of $V^+$.

**Note 7:** The response time specified is for a 100 mV input step with 5 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

**Note 8:** Positive excursions of input voltage may exceed the power supply level. As long as the other voltage remains within the common-mode range, the comparator will provide a proper output state. The low input voltage state must not be less than −0.3V (or 0.3V below the magnitude of the negative power supply, if used).

**Note 9:** At output switch point, $V_O \simeq 1.4V$, $R_S = 0\Omega$ with $V^+$ from 5V to 30V; and over the full input common-mode range (0V to $V^+$–1.5V), at 25˚C.

**Note 10:** Refer to RETS193AX for LM193AH military specifications and to RETS193X for LM193H military specifications.

## Ordering Information

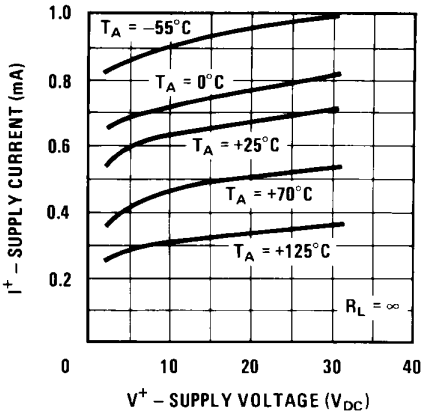
| Package | Temperature Range | Part Number | NSC Drawing |
|---|---|---|---|
| 8-Pin Metal Can | −55˚C to 125˚C | LM193H* | H08C |
| | | LM193H/883 | |
| | | LM193H-MLS | |
| | | LM193AH-MLS | |
| | | LM193AH-QMLV** | |
| | | LM193AH | |
| | | LM193AH/883 | |
| | −25˚C to 85˚C | LM293H | |
| | 0˚C to 70˚C | LM393H | |
| 8-Pin Ceramic DIP | −55˚C to 125˚C | LM193J/883* | J08A |
| | | LM193AJ/883 | |
| | | LM193AJ-QMLV** | |
| | | LM193AJ-MLS | |
| 8-Pin Molded DIP | 0˚C to 70˚C | LM393N | N08E |
| | −40˚C to 85˚C | LM2903N | |
| 8-Pin SOIC | 0˚C to 70˚C | LM393M | M08A |
| | | LM393MX | |
| | −40˚C to 85˚C | LM2903M | |
| | | LM2903MX | |
| 8-Bump (12 mils) micro SMD | 0˚C to 70˚C | LM393TL | TLA08AAA |
| | | LM393TLX | |
| | −40˚C to 85˚C | LM2903ITL | |
| | | LM2903ITLX | |

**Note:** * Also available per LM38510/11202

**Note:** ** See STD Mil DWG 5962-94526

# Typical Performance Characteristics LM193/LM293/LM393, LM193A

**Supply Current**

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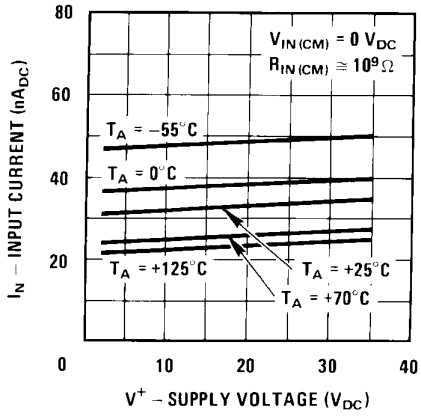
**Input Current**

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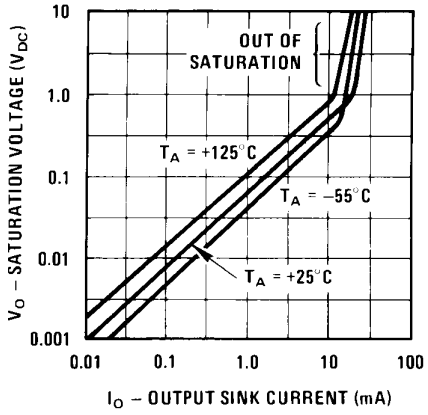
**Output Saturation Voltage**

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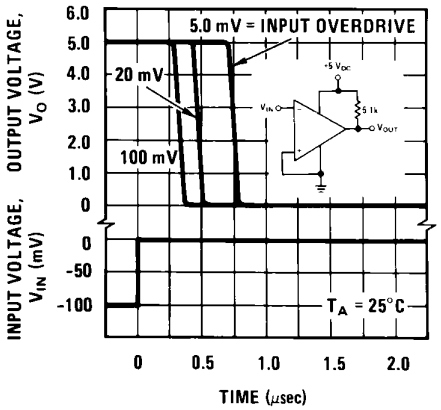
**Response Time for Various Input Overdrives—Negative Transition**

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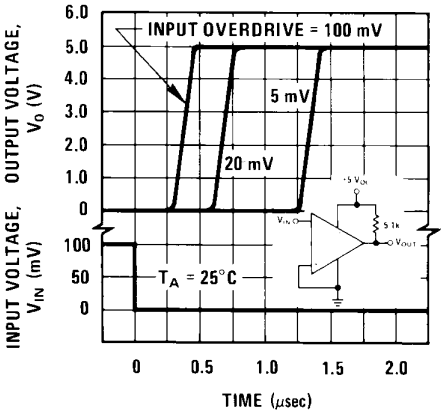
**Response Time for Various Input Overdrives—Positive Transition**

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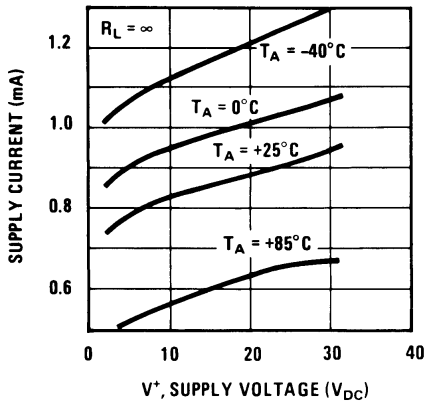
# Typical Performance Characteristics LM2903

**Supply Current**

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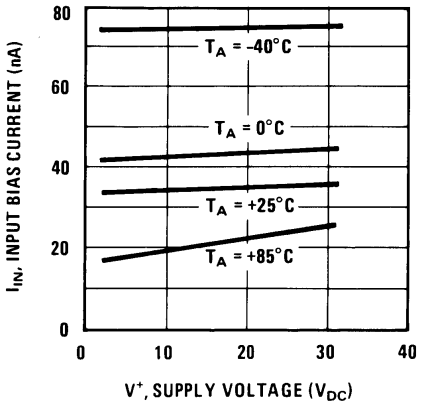
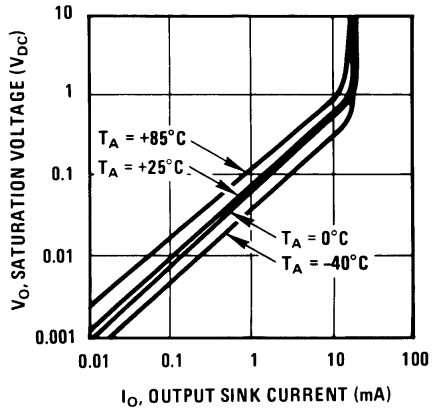
**Input Current**



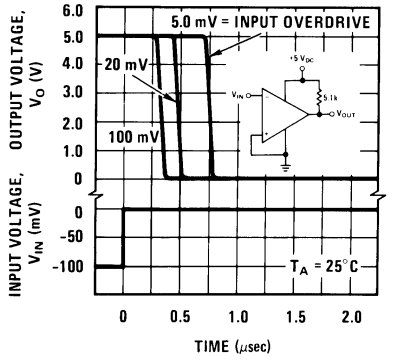

00570931

**Output Saturation Voltage**




00570932

**Response Time for Various Input Overdrives — Negative Transition**

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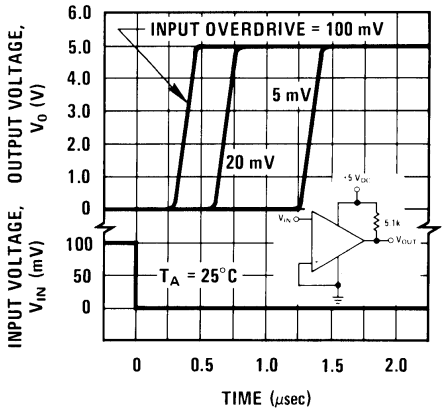
**Response Time for Various Input Overdrives — Positive Transition**

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## Application Hints

The LM193 series are high gain, wide bandwidth devices which, like most comparators, can easily oscillate if the output lead is inadvertently allowed to capacitively couple to the inputs via stray capacitance. This shows up only during the output voltage transition intervals as the comparator change states. Power supply bypassing is not required to solve this problem. Standard PC board layout is helpful as it reduces stray input-output coupling. Reducing the input resistors to < 10 kΩ reduces the feedback signal levels and finally, adding even a small amount (1.0 to 10 mV) of positive feedback (hysteresis) causes such a rapid transition that oscillations due to stray feedback are not possible. Simply socketing the IC and attaching resistors to the pins will cause input-output oscillations during the small transition intervals unless hysteresis is used. If the input signal is a pulse waveform, with relatively fast rise and fall times, hysteresis is not required.

All input pins of any unused comparators should be tied to the negative supply.

The bias network of the LM193 series establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 2.0 $V_{DC}$ to 30 $V_{DC}$.

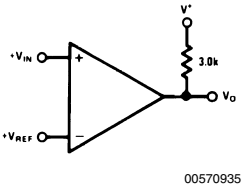
It is usually unnecessary to use a bypass capacitor across the power supply line.

The differential input voltage may be larger than $V^+$ without damaging the device (Note 8). Protection should be provided to prevent the input voltages from going negative more than –0.3 $V_{DC}$ (at 25˚C). An input clamp diode can be used as shown in the applications section.

The output of the LM193 series is the uncommitted collector of a grounded-emitter NPN output transistor. Many collectors can be tied together to provide an output OR'ing function. An output pull-up resistor can be connected to any available power supply voltage within the permitted supply voltage range and there is no restriction on this voltage due to the magnitude of the voltage which is applied to the $V^+$ terminal of the LM193 package. The output can also be used as a simple SPST switch to ground (when a pull-up resistor is not used). The amount of current which the output device can sink is limited by the drive available (which is independent of $V^+$) and the β of this device. When the maximum current limit is reached (approximately 16mA), the output transistor will come out of saturation and the output voltage will rise very rapidly. The output saturation voltage is limited by the approximately 60Ω $r_{SAT}$ of the output transistor. The low offset voltage of the output transistor (1.0mV) allows the output to clamp essentially to ground level for small load currents.

## Typical Applications ($V^+$=5.0 $V_{DC}$)

**Basic Comparator**

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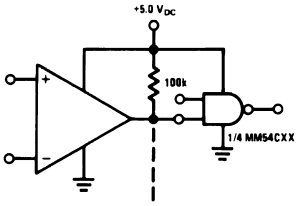
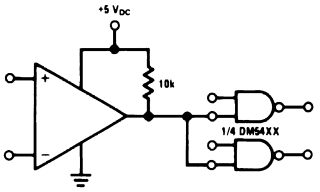
**Driving CMOS**



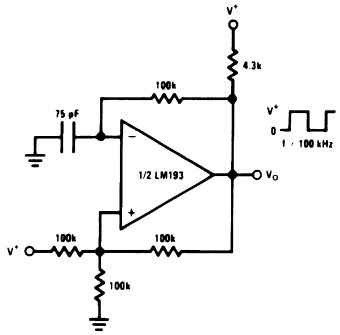

00570936

**Driving TTL**



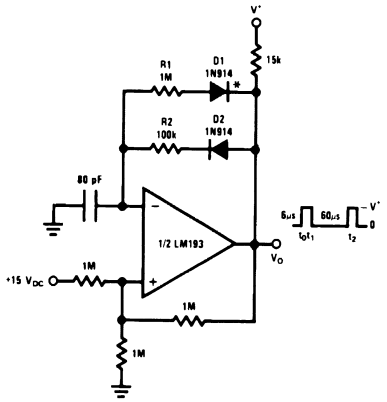

00570937

**Squarewave Oscillator**




00570938

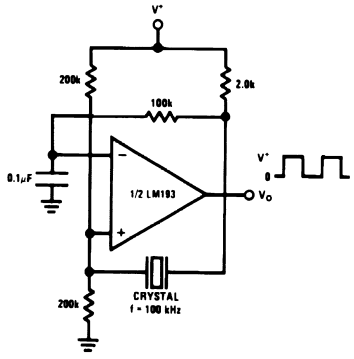
**Pulse Generator**




00570939

* For large ratios of R1/R2, D1 can be omitted.

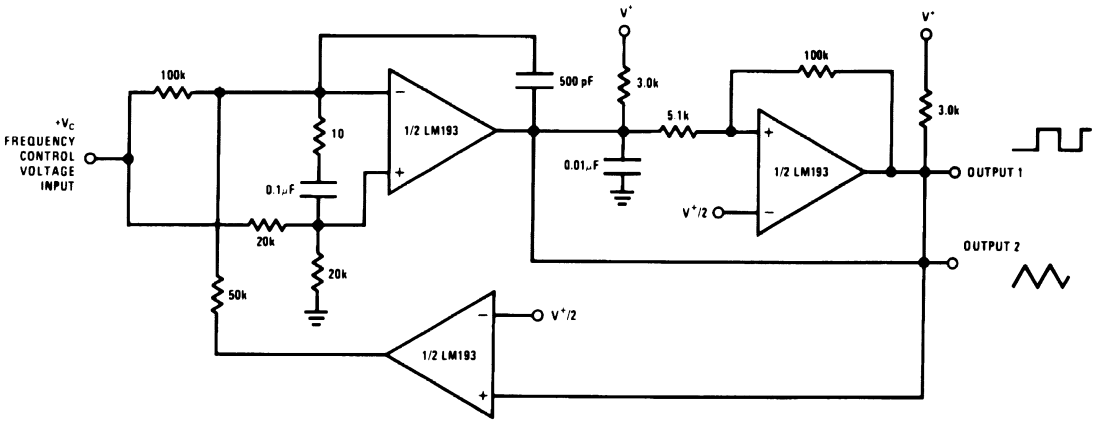
**Crystal Controlled Oscillator**




00570940

## Typical Applications ($V^+$=5.0 $V_{DC}$) (Continued)

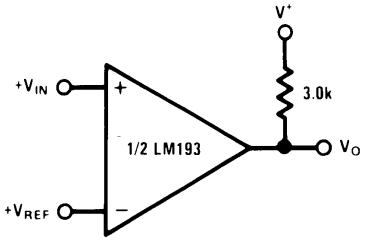
**Two-Decade High Frequency VCO**




00570941

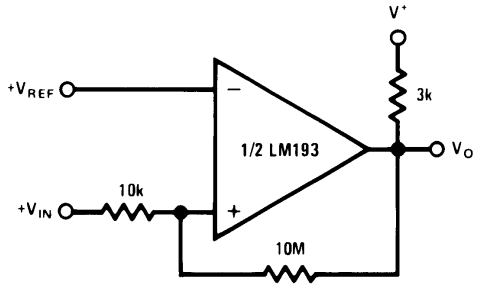
V* = +30 $V_{DC}$
+250 $mV_{DC} \leq V_C \leq$ +50 $V_{DC}$
700Hz $\leq f_o \leq$ 100kHz

**Basic Comparator**



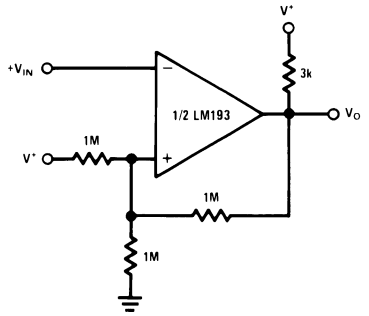

00570906

**Non-Inverting Comparator with Hysteresis**



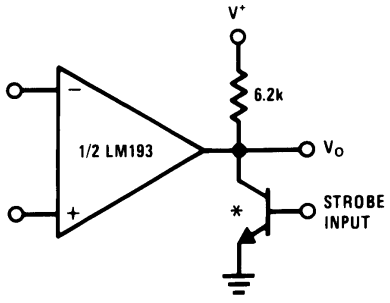

00570909

**Inverting Comparator with Hysteresis**




00570910

**Output Strobing**

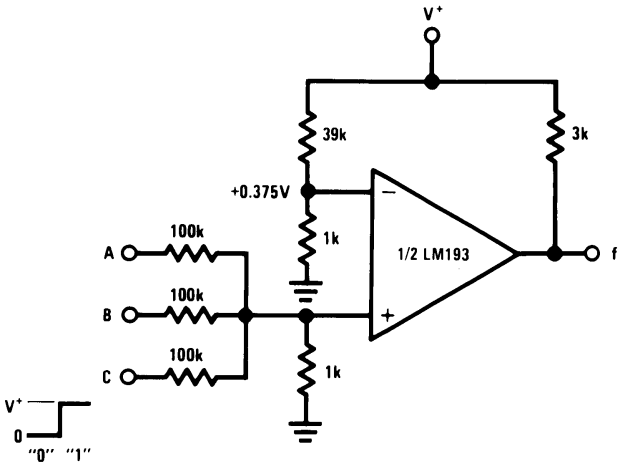



* OR LOGIC GATE WITHOUT PULL-UP RESISTOR

00570911

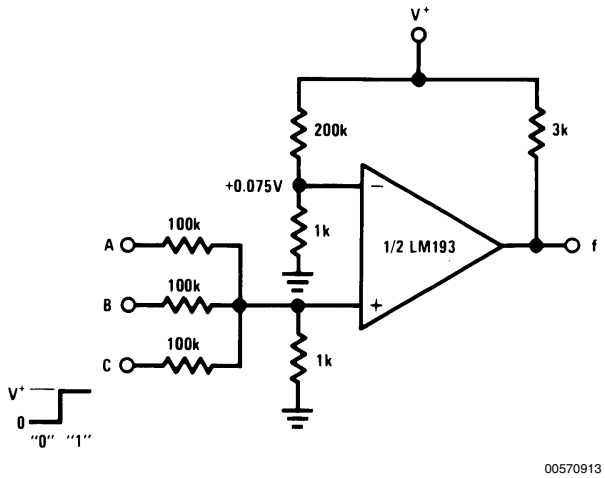
## Typical Applications ($V^+$=5.0 $V_{DC}$) (Continued)

**AND Gate**



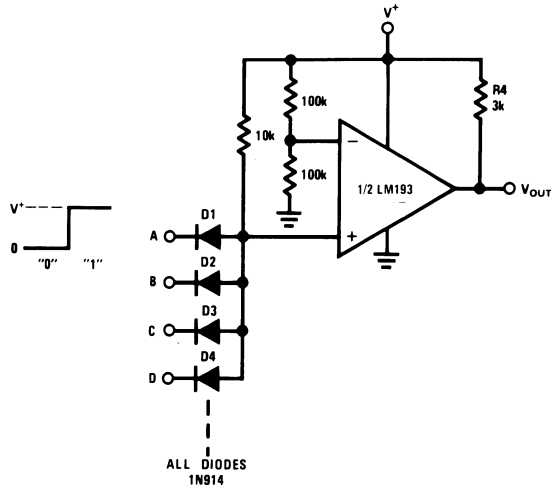

00570912

**OR Gate**



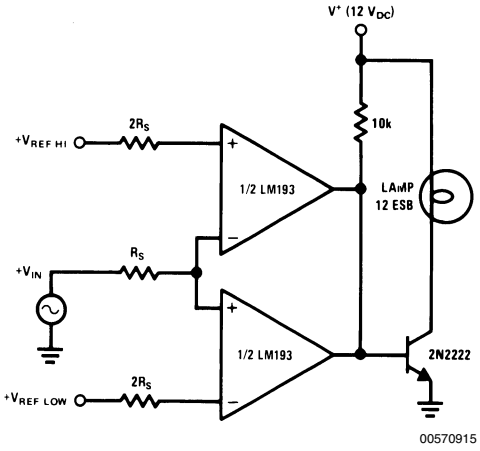

00570913

**Large Fan-in AND Gate**



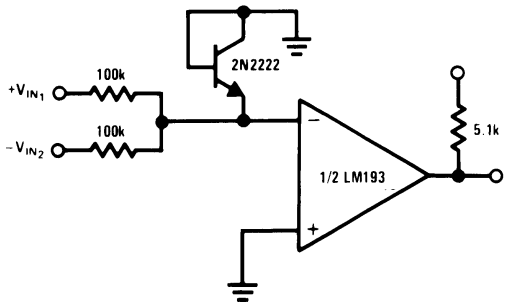

00570914

**Limit Comparator**



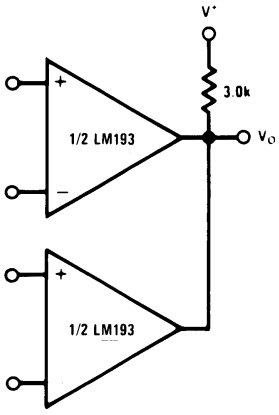

00570915

**Comparing Input Voltages of Opposite Polarity**




00570916

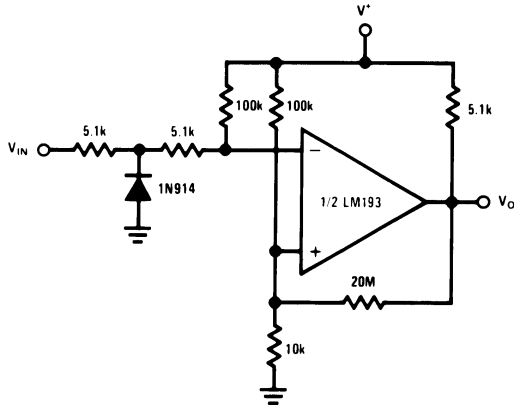
**ORing the Outputs**




00570917

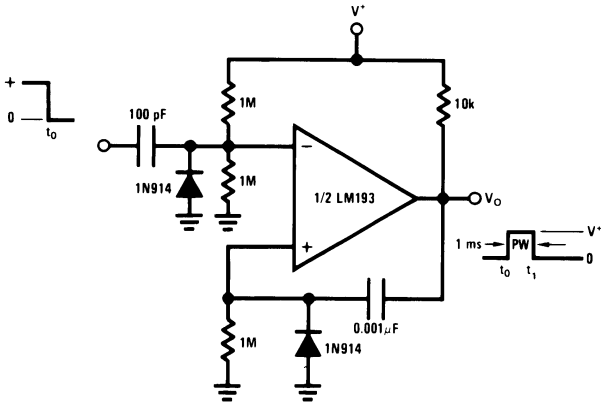
## Typical Applications ($V^+$=5.0 $V_{DC}$) (Continued)

**Zero Crossing Detector (Single Power Supply)**



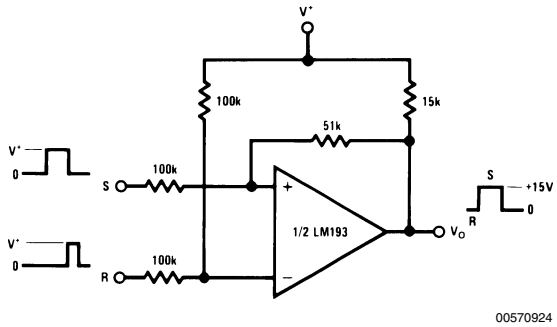

00570921

**One-Shot Multivibrator**



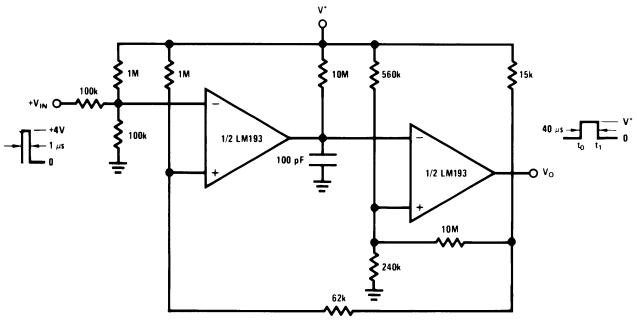

00570922

**Bi-Stable Multivibrator**



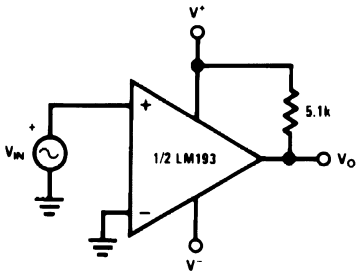

00570924

**One-Shot Multivibrator with Input Lock Out**



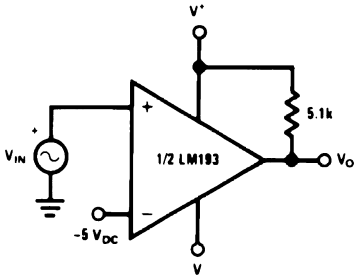

00570923

**Zero Crossing Detector**




00570943

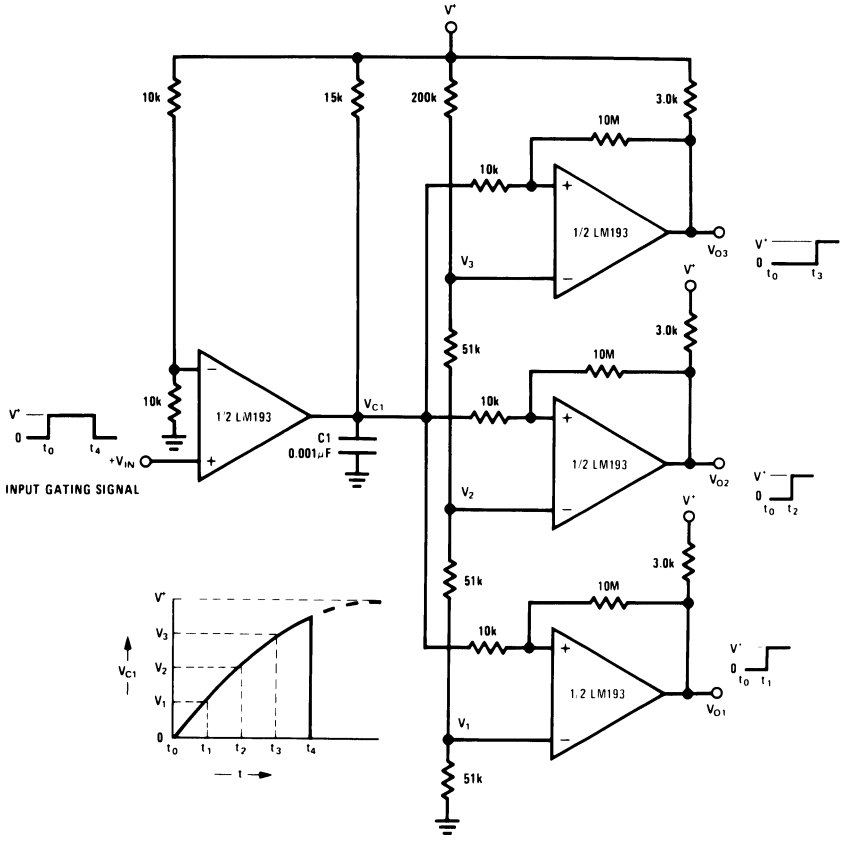
**Comparator With a Negative Reference**




00570944

## Typical Applications ($V^+$=5.0 $V_{DC}$) (Continued)

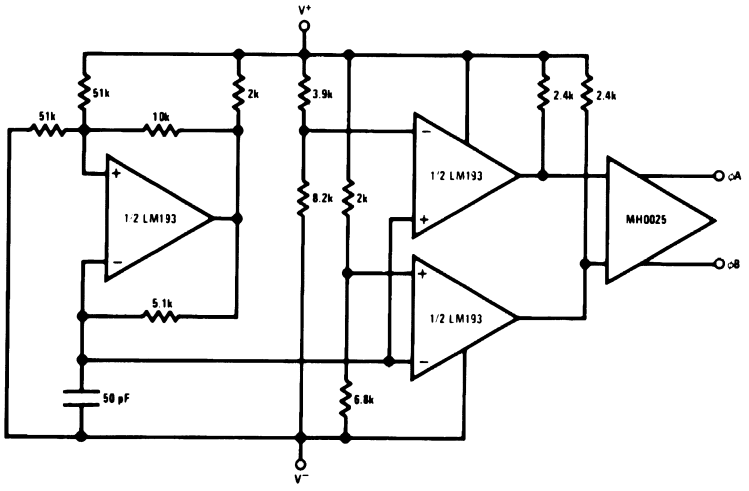
**Time Delay Generator**




00570907

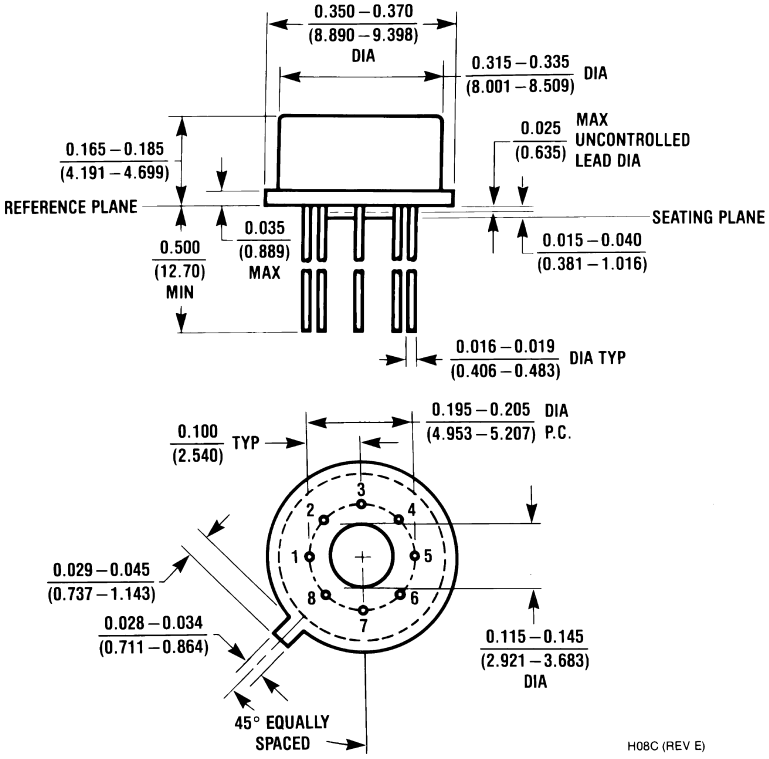
## Split-Supply Applications ($V^+$=+15 $V_{DC}$ and $V^-$=−15 $V_{DC}$)

**MOS Clock Driver**

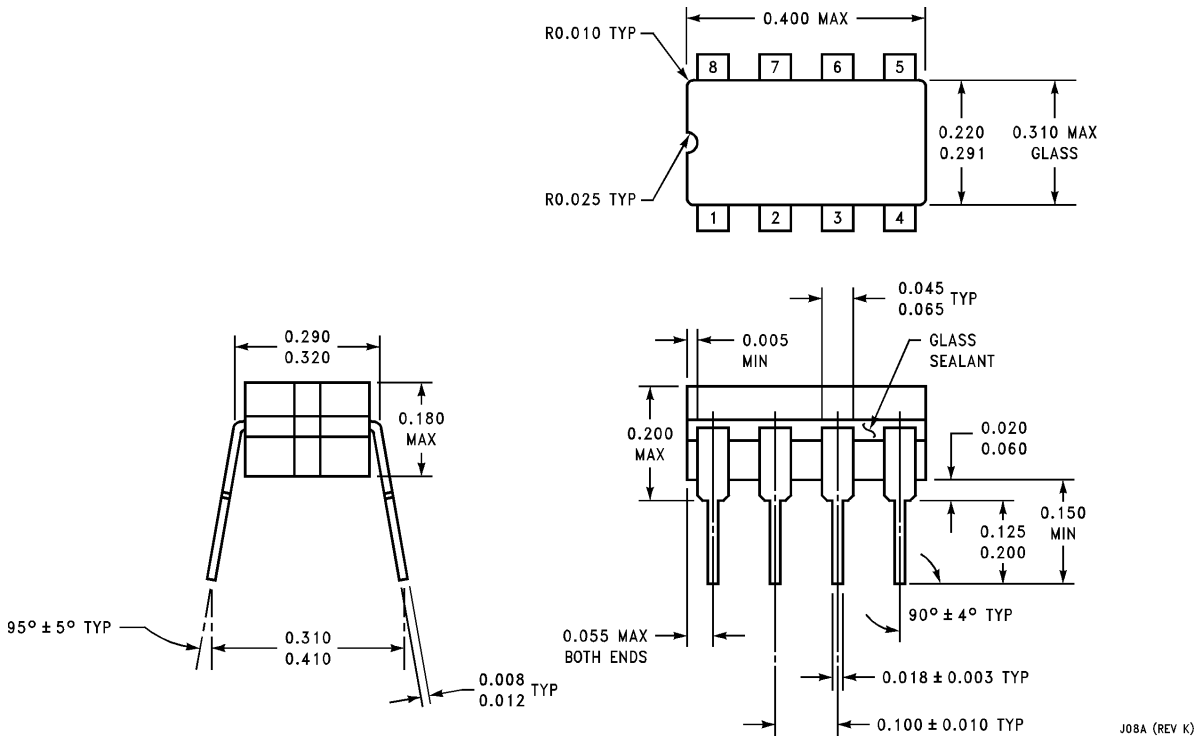



00570942

## Physical Dimensions inches (millimeters) unless otherwise noted

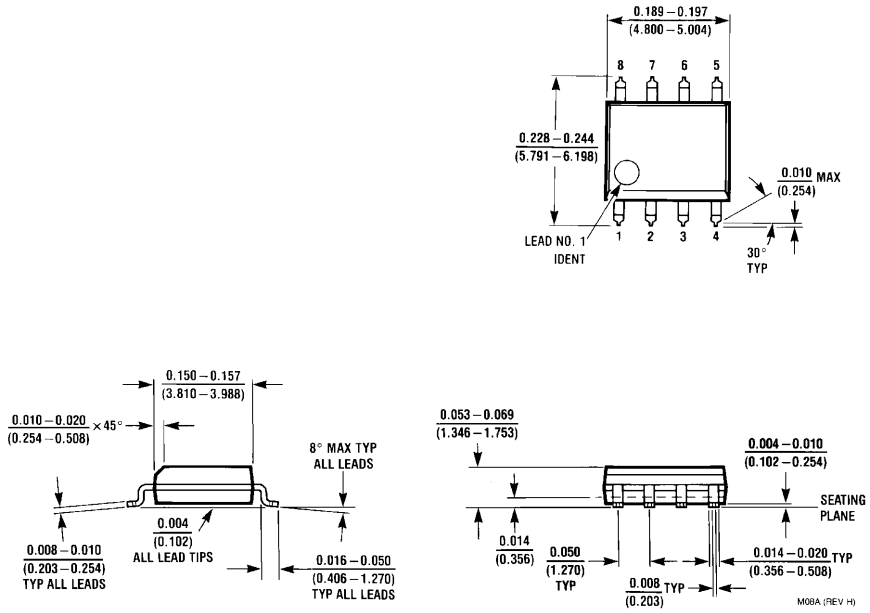



**Metal Can Package (H)**
**NS Package Number H08C**

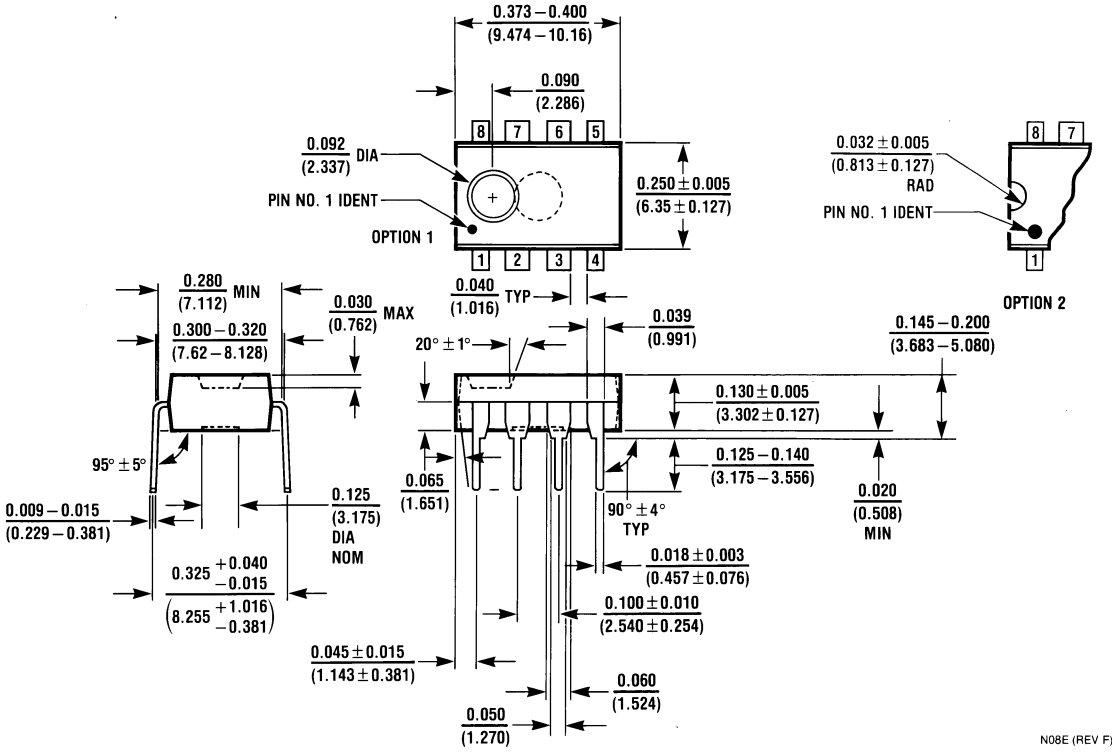



**Ceramic Dual-In-Line Package**
**NS Package Number J08A**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

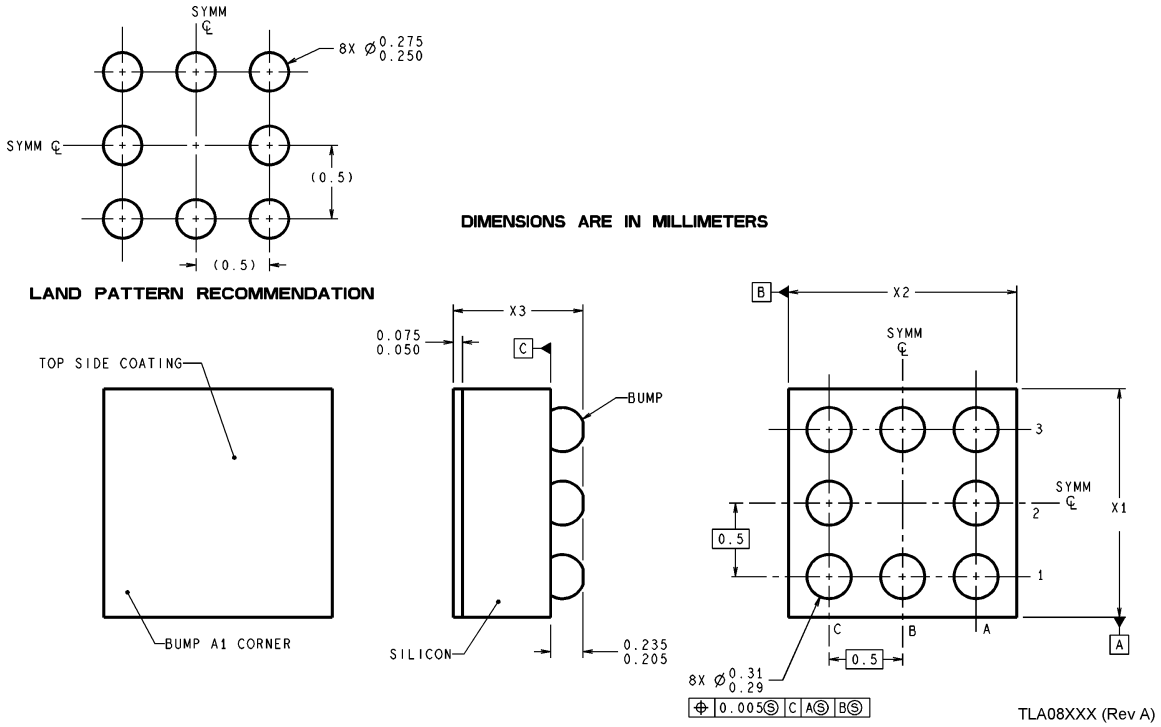



**SOIC Package**
**NS Package Number M08A**




**Molded Dual-In-Line Package (N)**
**NS Package N08E**

## Physical Dimensions inches (millimeters) unless otherwise noted (Continued)




NOTE: UNLESS OTHERWISE SPECIFIED

1. EPOXY COATING
2. 63Sn/37Pb EUTECTIC BUMP
3. RECOMMEND NON-SOLDER MASK DEFINED LANDING PAD.
4. PIN A1 IS ESTABLISHED BY LOWER LEFT CORNER WITH RESPECT TO TEXT ORIENTATION REMAINING PINS ARE NUMBERED COUNTERCLOCKWISE.
5. XXX IN DRAWING NUMBER REPRESENTS PACKAGE SIZE VARIATION WHERE $X_1$ IS PACKAGE WIDTH, $X_2$ IS PACKAGE LENGTH AND $X_3$ IS PACKAGE HEIGHT.
6. REFERENCE JEDEC REGISTRATION MO-211, VARIATION BC.

**8-Bump (12 mil) micro SMD Package**
**NS Package TLA08AAA**
**$X_1$ = 1.514mm $X_2$ = 1.514mm $X_3$ = 0.600mm**

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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